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U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

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**DOMESTIC PREPAREDNESS PROGRAM:
PHASE 2
SARIN (GB) AND DISTILLED SULFUR MUSTARD (HD)
VAPOR CHALLENGE TESTING
OF COMMERCIAL SELF-CONTAINED BREATHING APPARATUS
FACEPIECES**

**Raymond R. Lins
Lee E. Campbell**

RESEARCH AND TECHNOLOGY DIRECTORATE

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14. ABSTRACT Results of performance testing of three types of commercial self-contained breathing apparatus (SCBA) facepieces are described. A series of tests were performed to determine sarin (GB) and distilled sulfur mustard (HD) vapor breakthrough of SCBA facepieces using manikin head form and simulated breathing.													
15. SUBJECT TERMS <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">GB</td> <td style="width: 50%;">Mustard</td> </tr> <tr> <td>HD</td> <td>Self-Contained Breathing Apparatus</td> </tr> <tr> <td>Sarin</td> <td>Chemical Agent Breakthrough</td> </tr> <tr> <td>SCBA</td> <td>Agent Challenge Testing</td> </tr> </table>						GB	Mustard	HD	Self-Contained Breathing Apparatus	Sarin	Chemical Agent Breakthrough	SCBA	Agent Challenge Testing
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Sarin	Chemical Agent Breakthrough												
SCBA	Agent Challenge Testing												
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EXECUTIVE SUMMARY

This report presents the results of testing three different self-contained breathing apparatus (SCBA) facepieces against vapors of sarin (GB), a nerve agent, and distilled sulfur mustard (HD), a vesicant agent. The challenge concentration of both agents was 200 mg/m³. These respirators are normally used in a lower challenge concentration. However, in a laboratory setting, the higher concentration gives a more rigorous evaluation of each item.

The air cylinders, supplied with the respirators, were not used during the agent tests. Instead, high-pressure air from the laboratory was used to supply breathing air to the facepieces, which allowed the tests to run for 60 min for each item. The nominal times of use for the three SCBAs are 15 and 30 min (one SCBA has an optional 60-min cylinder).

Three tests were performed on each type of facepiece for both agents. One facepiece, the 3M™ SCBAG™, resisted HD and GB for 60 min. Two of the three Interspiro Spiroscape facepieces resisted HD for 60 min; however, the third one was later found to be defective. The HD vapor leaked into the facepiece within 12 min. One Interspiro Spiroscape facepiece resisted GB for 30 min, but agent seeped inside the other two within 4 min. For all three tests, the North Model 821 resisted HD for 60 min and GB for 25, 28, and 32 min.

Terms used in this report are included in the glossary.

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PREFACE

The work described in this report was authorized under the Expert Assistance Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in March 2000 and completed in October 2002.

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DOMESTIC PREPAREDNESS PROGRAM:
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1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction (WMD). The DoD responded by forming the Domestic Preparedness Program (DPP) that same year. One objective of the DPP is to enhance responses by the federal, state, and local emergency and hazardous material (HAZMAT) agencies to nuclear, biological, and chemical (NBC) terrorism incidents. As part of an effective response, emergency and HAZMAT personnel responding to an incident are required to use personal protective equipment (PPE) as protection from exposure to chemical and/or biological agents. The specific PPE used by these personnel is dependent upon the situation encountered and the PPE held in inventory. In some cases, commercial self-contained breathing apparatus (SCBA) may be used when entering a contaminated or potentially contaminated area.

Under the DPP, the U.S. Army Edgewood Chemical Biological Center (ECBC), U.S. Army Research, Development and Engineering Command (RDECOM), is to perform chemical agent vapor testing on some commercial SCBAs. A SCBA, an atmosphere-supplying respirator, allows the user to carry a compressed gas cylinder of air.

2. OBJECTIVES AND SCBA DESCRIPTIONS

The objective of this project was to determine the occurrence of inward leakage or permeation of agent through the facepieces of three commercial SCBAs exposed to 200-mg/m³ challenge concentrations of GB and HD vapors. The facepieces were mounted on a manikin in a closed exposure chamber and operated in the pressure-demand mode by a breather pump. The 200-mg/m³ challenge concentration enables fast detection of leaks and/or permeation, which permits easy evaluation of the integrity of the respirator. High-pressure air was supplied to the facepieces from a laboratory source. Following exposure, air samples from the eye and nose areas inside the facepieces were analyzed by MINICAMS.

Three tests for each agent were conducted on each SCBA type. None of the three SCBAs was intended for use in an immediately dangerous to life or health (IDLH) agent environment.

2.1 3M™ SCBAG™ System.

The 3M™ SCBAG™ (BA-4430M) system, from 3M™ Occupational Health and Environmental Safety Division (St. Paul, MN), comes in a carrying bag that opens to form a vest with the SCBA system already in place. The system includes a full facepiece with speaking diaphragm, a soft double-flange seal, and a 30-min, 4500-psi cylinder of air. If the wearer has to remain in the area for a longer period, the system has an optional airline connection. This system is certified by the National Institute for Occupational Safety and Health (NIOSH), Washington, D.C.

2.2 North Model 821 System.

The North Model 821 system (facepiece 80004, demand valve 80014), from North Safety Products (Cranston, RI), has either a 30- or 60-min air cylinder worn on the back in a harness. The system consists of a full facepiece constructed of soft silicone, a dual sealing flange, and a speaking diaphragm. An oronasal cup reduces fogging on the polycarbonate lens. At peak inhalation, the demand valve can provide over 300 L of air per min. This system is also NIOSH certified.

2.3 Interspiro Spiroscape.

The Interspiro Spiroscape [Interspiro, Incorporated (Branford, CT)] is not strictly a SCBA, but it is included in these tests because it contains a 10- or 15-min cylinder of air. Actually, the Interspiro Spiroscape is an emergency escape breathing apparatus. The hood has a latex rubber neck seal. The inner mask has an exhalation valve that minimizes fogging and carbon dioxide build-up, which eliminates the need for a demand valve. NIOSH certifies this item as a compressed air emergency escape breathing apparatus.

3. CHEMICAL AGENT TESTING

3.1 Chemical Agent Testing Equipment.

3.1.1 Vapor Generator.

The GB and HD vapors were generated using a syringe pump that injected liquid agent into a heated tee in the air dilution line. The injection rate maintained the concentration of agent specified in the test plan. The agent was vaporized in the heated tee and carried by the dilution air into the mixing chamber. The vapor was then injected into the exposure chamber. An IR Ambient Air Analyzer, (MIRAN) Model 1A, was used to monitor the agent concentration in the exposure chamber during the test. The MIRAN was standardized by injecting known volumes of Chemical Agent Standard Analytical Reference Material (CASARM) grade agent into the air in the closed sampling cell, which is recirculated by an external pump. A probe located in front of the facepiece monitored the agent concentration.

3.1.2 SCBA Facepiece Exposure Chamber.

The exposure chamber was a Plexiglas box of approximately 2 ft³ with a removable front panel. The chamber was supported by four legs about 4 in. long, which allowed air to flow under it during testing inside a fume hood. Because agent-air mixtures passed through the exposure chamber during the test, the outlet ports on top of the chamber were covered by military M12A1 filters to scrub agent from the passing air. Other ports in the chamber walls were used for the following reasons:

- to introduce the agent challenge into the chamber
- to attach pressure gauges
- to introduce liquid aerosol for preliminary leak testing
- to monitor the agent concentration inside the chamber

To ensure that the challenge concentration was not diluted by clean air, the challenge airflow rate was double that of the minute flow of the breather pump.

The test fixture, which is called the SiMulant Agent Resistant Test MANikin (SMARTMAN), consists of a medium human head form with a movable face section, and an inflatable peripheral seal to ensure secure sealing of the facepiece section of the mask.

The mouth orifice of the fixture is connected to a breather pump. There are two sampling tubes in the nose, one in the eye, and one in the forehead. These tubes run down through the interior of the fixture, through the floor of the chamber, and connect to remote detectors.

3.1.3 Breather Pump.

The Military Breather Pump E1R1 (Jaeco Fluid Systems, Incorporated, Exton, PA) was used to simulate breathing through the SCBA facepieces. The E1R1 is a reciprocating pump that produces a harmonic (sinusoidal) breathing pattern by means of a reduction planetary gear system, which incorporates a Scotch Yoke. The minute volume (liters pumped in 1 min) and the number of strokes (breaths) per min can be adjusted on this pump. The peak flow produced by the pump is approximately π times the minute volume. In the tests performed, the peak flow was approximately 78 L/min.

3.1.4 MINICAMS.

The Miniature Continuous Air Monitoring System (MINICAMS) is a gas chromatograph (GC) equipped with a flame photometric detector and a preconcentrator tube. The preconcentrator tube is a small diameter tube containing an adsorbent material to collect agent vapor present in the air sample drawn through this tube for a set period of time. The tube is then heated to desorb the agent and introduce it into the column first and then subsequently into the detector. By preconcentrating the agent, the detection limit is lowered. MINICAMS software calculates the amount of agent detected over the sampling period. The MINICAMS is standardized by injecting known amounts of agent into the column.

3.2 Chemical Agent Testing.

The SCBA facepiece was mounted on the SMARTMAN by tightening the harness straps. The peripheral seal was inflated (3-5 psi) to form a tight seal against the inside of the facepiece. This seal (head form) is artificially good and may not be representative of the seal obtained by a human facepiece user. Therefore, it is important that users follow the manufacturers' instructions to develop a good seal of the facepiece against the face.

Before an agent test was started, a liquid aerosol leak test was performed using the TDA-99M Aerosol Leak Detector. This test is a preliminary check that can isolate leaks. The detector section of the tester was connected to one of the SMARTMAN sampling ports inside the respirator, and the aerosol was directed through a hollow wand against the facepiece and the seal. The breather pump was turned on. If no leakage was detected, the chamber was closed, and the aerosol was injected into the exposure chamber to challenge the entire system. If leakage was detected, the leak path was found and corrected, and the agent test was performed.

For the agent test, the MINICAMS detector was connected to the eye and nose ports to monitor for agent presence inside a facepiece. The agent challenge passed from the mixing chamber into the SCBA exposure chamber. Each type of facepiece was tested three times with HD and three times with GB. Table 1 lists the conditions used for testing.

Table 1. Conditions Used for Testing SCBA Facepieces

Rate of airflow through exposure chamber	50 L/min
Concentration of agent challenge	200-mg/m ³
Total test time if breakthrough is not observed.....	60 min
Temperature of test chamber.....	25 ± 3 °C
Flow rate of breather pump	25 L/min
Pump strokes per minute	25
Volume per breath.....	1 L

3.3 Chemical Agent Test Results and Discussion.

The test results on the three types of SCBA are presented in Table 2. If no agent was detected inside the facepiece, the result is noted as below detection limit (BDL). If agent was detected inside the facepiece, the time from the beginning of the test to a concentration of 0.007 mg/m³ for GB and 0.003 mg/m³ for HD is given in minutes.

The 3M™ SCBAG™ resisted permeation/penetration of GB and HD for the 60-min test time. Two of the Interspiro Spiroscape respirators tested with HD showed no agent inside the facepiece after 60 min. The TDA-99M Leak Tester indicated a small hole in the facepiece of the third Interspiro Spiroscape. Because a replacement was not available, the hole

was covered with a piece of tape before the HD test. However, agent was detected inside the facepiece after 12 min. This test cannot be regarded as a valid test. The Spiroscape tested against GB had agent inside the facepiece after 30 min in one case and within <4 min in the other two. Although the North Model 821 SCBA resisted HD for 60 min in all three tests, GB was detected inside the three facepieces after 25, 28, and 32 min.

The aerosol leak test is performed to assure a tight seal between the facepiece and the test fixture, and to detect any pinhole leak paths. No detection of aerosol inside the facepiece does not indicate that vapor will not penetrate the facepiece since vapor can pass through miniscule apertures that an aerosol cannot. Vapor can penetrate seals, exhalation valves, and holes much too small for aerosols to penetrate. Vapor can also permeate susceptible areas of the polymer of the facepiece.

Table 2. Detection of Agent Inside Facepiece

Respirator	Test Duration (min)	Agent	Results 1 hr mg/m ³	BP (min)
3M™ SCBAG™ (BA-4430M)	60	HD	BDL	NA
			BDL	NA
			BDL	NA
	60	GB	BDL	NA
			BDL	NA
			BDL	NA
Interspiro Spiroscape	60	HD	Detected	12
			BDL	NA
			BDL	NA
	60	GB	Detected	30
			Detected	<4
			Detected	<4
North Model 821	60	HD	BDL	NA
			BDL	NA
			BDL	NA
	60	GB	Detected	28
			Detected	25
			Detected	32

BDL - Below Detection Limit

BP - Break Point

NA - Not Applicable

4. CONCLUSIONS

The 3M™ SCBAG™ (BA-4430M) resisted HD and GB vapor for 1 hr. This facepiece might be considered useful in agent vapor environments. The Interspiro Spiroscape and North Model 821 gave inconsistent results. When tested against both agents for 1 hr, each resisted HD but not GB. Without further testing, it is inconclusive whether these two should be considered for use in agent vapor environments.

GLOSSARY

Ambient Air Analyzer (MIRAN) Model 1A

Manufactured by Thermo Environmental Instruments, Incorporated, the analyzer is an infrared absorption based detector that uses a long path length cell (up to 20 m) into which the air sample is introduced. This analyzer is used to monitor the challenge concentration of vapor in the test chamber.

Facepiece

Portion of a respirator that covers the wearer's nose and mouth (a full facepiece also covers the eyes). The facepiece, which should make a gas- or dust-tight seal with the face, is supported by headbands, and contains exhalation valves and connectors for breathing air.

HD

The military symbol for mustard, a vesicant (blister) chemical agent. The chemical name is bis(2-chloroethyl)sulfide.

Leak Detector TDA-99M

Manufactured by Air Techniques, Incorporated, Baltimore, MD. The TDA-99M is used for detecting aerosol leaks in the seal of the respirator facepiece secured to the SMARTMAN test fixture and the mechanical seals of the respirator. The device generates a liquid oil aerosol (Emory 3004) that is used to detect leakage into the interior of the respirator.

MINICAMS®

Trade name for a chemical agent detector in which the agent is adsorbed from a specified volume of air into an adsorbent tube from which the agent is then desorbed into the injection port of a gas chromatograph for analysis (quantitation).

Sarin

An organophosphorus nerve agent known as GB. The chemical name is isopropyl methylphosphonofluoridate. GB reacts with the enzyme, cholinesterase, and subsequently interferes with the transmission of nerve impulses.

SCBA

An Open-Circuit Self-Contained Breathing Apparatus that provides the wearer with an atmosphere independent of ambient air. Air is supplied by a compressed gas cylinder worn by the user or by a compressor hose.

SMARTMAN

Manufactured by ILC Dover, Frederica, DE, the SMARTMAN is a hollow cast zinc model of the human head and upper body. The head features an anatomically correct surface consisting of dimensional eyes, nose, ears, mouth, forehead, and chin. The facial features are on a movable section of the head to facilitate the installation and removal of a peripheral front face rubber seal. The seal fits into a channel between the face and the fixed part of the head, and it is inflated to press against the inside of the facepiece seal area to assure against leakage.

Syringe Pump

A multirange, variable rate infusion pump, the syringe pump is used to inject liquid agent at a controlled rate into an air stream to generate a vapor challenge. The liquid agent is contained in a syringe connected to a flexible cannula. The plunger of the syringe is driven at a controlled rate by the pump to deliver a constant flow of agent. The concentration of agent is adjusted by changing the speed setting of the pump.